Holography

Working Principle and Applications

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***Abstract*— Holography is the science of making holograms which are usually intended for displaying three dimensional images. It is a physical structure that diffracts light into an image. A holographic image can be seen looking into an illuminated holographic print by shining a laser through a hologram and projecting a image on the screen. The paper reviews the basic concepts of holography, discussing in depth of the principle of interference on which it is based, and outlines the broad applications of holography. We finally present a short conclusion in the end after analyzing the various aspects of holography.**

Keywords—holography; hologram; interferometry; optics

I. INTRODUCTION

Gabor, who invented holography in 1947, introduced the term using two Greek words: “Holos” - whole and “Graphe” -writing. It simply means that the recorded holographic image of the object contains whole optical information about the object – Amplitude and Phase information of the light scattered from the object. Ideally, the hologram is a three-dimensional image reproduced from interference pattern recorded by coherent light beans and holography is a process of reconstructing and writing a hologram.

White light from the sun or a light bulb is a combination of every colour of light in the spectrum, which is not useful for a hologram. However, a laser shines light in a thin, intense beam which is of one colour which implies that they are uniform and in-phase. When two laser beams interact, a single new wave pattern is produced: the hologram. Traditionally, holography was usually static and the application limited to displays, but with development in this science, it is used in various field of applications, including art, security, data storage and so on.

The whole article is organized as follow: section 2 provides background knowledge to understand holography, section 3 and 4 introduce the recording and reconstruction process, followed by section 5 which talks about application of holography. At the end is the conclusion, acknowledgement and reference.

II. BASIC PRINCIPLES OF HOLOGRAM AND IMAGE RECONSTRUCTION

A. Basics of Holography

A hologram is a recording in a two- or three-dimensional medium of the interference pattern formed when a point source of light (the reference beam) of fixed wavelength encounters light of the same fixed wavelength arriving from an object (the object beam).

Ordinary light is made up of many different wavelengths, none of which maintains a fixed phase relationship with each other or with themselves over a period of time. It has poor temporal coherence. Such incoherent light is not capable of interfering with itself, which is the most important for the application of holography. So lasers are used to produce light beams which are coherent over 10^10 wavelengths and more.

- Interference: It is a phenomenon in which two waves superpose to form a resultant wave of greater or lower amplitude. Interference usually refers to the waves that are coherent with each other.
- Diffraction grating: The recorded light pattern isdiffraction grating. When it is illuminated by only one of the waves used to create it, it can be shown that one of the diffracted waves emerges at the same angle at which the second wave was originally incident so that the second wave has been reconstructed. Thus the recorded light pattern is a holographic recording.
- Photographic plate: Only records the intensities.
- Interference Pattern: Contains the phase information.

B. Experimental Setup

For creating holograms we need,

1) Laser
2) Beam splitter
3) Photographic plate or Hologram plate
4) Mirror

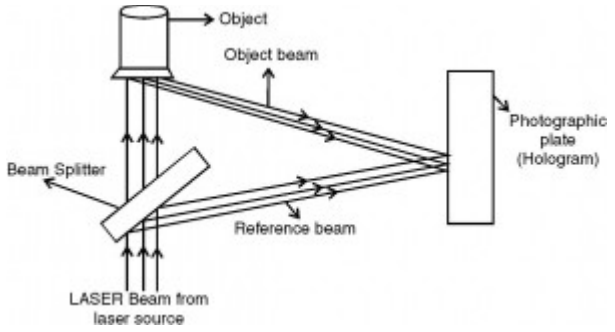
It involves two processes:

a) Recording a Hologram

b) Reconstructing a Hologram

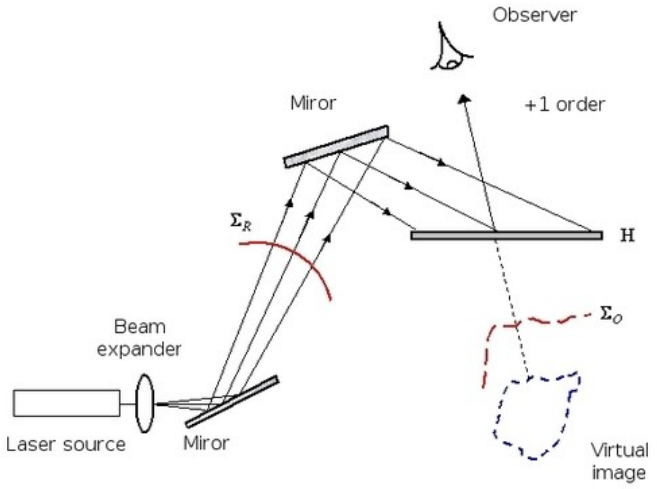
III. RECORDING A HOLOGRAM

A coherent light from a Laser is directed on a Beam-Splitter. A Beam-Splitter divides the laser beam into two identical beams, which are aimed in two different directions. The two beams are Object beam and Reference beam. The object beam is reflected by the surface of the object onto the plate. The reference beam directly falls onto the plate. So the laser beams interfere with each other. A laser light hologram is recorded.



To capture the three-dimensionality of an object, the film stores not only the amplitude but also the phase of the light rays. This recorded interference pattern actually contains much more information that a focused image, and enables the viewer to view a true three-dimensional image which exhibits parallax.

IV. Reconstructing a Hologram



The laser light hologram can be reconstructed by using the same laser light as for recording. In the reconstruction of hologram, the object beam and the reference beam strike the hologram plate from opposite sides.

To prevent external light from interfering, holograms are usually taken in darkness, or in low level light of a different color from the laser light used in making the hologram. Also, holography requires a specific exposure time, which can be controlled by electronically timing the laser.

V. Application of Holography

Holography is widely used in various fields of application, including art, data storage, security and so on. This section introduce some common applications of the holographic technique.

A. Holographic Interferometry

As the holographic recording process is dependent on the interference pattern generated due to the two coherent, monochrome optical waves, the holographic image is the comparitive shape betwween these two waves. The holographic interferometry utilises this property to enable static and dynamic displacement of objects with optically rough surfaces to be measured to optical interferometric precision, with applications in industrial non-destructive testing and stress, strain and vibration analysis.

B. Data Storage

One of the application of holography is information storage. A single image can contain huge information which can be accessed by reflecting light from different angles unlike traditional optical storage methods like CD-ROM. Holograms are being extensively researched for high capacity data storage devices for entertainment and computing purposes. Though there are technical and material challenges to holographic data storage, they could yield capacities of a trillion bits per square centimeter. Fast progress in multiple-frequency holography offers atleast the theoritical potential for managing high data densities and readout speeds.

In holographic data storage, data is first turned into a two dimensional pattern of light by a spatial light modulator which is an array of light switches that can store as many as one million bits or pixels. Laser light is beamed through the SLM to the recording medium, such as a photopolymer, while a reference beam also illuminates the medium so that interference patterns are created. These expose the medium by generating corresponding differences in optical properties such as refractive index or absorption. Many pages of holograms can be multiplexed onto the same medium, either by varying the angle or phase of the reference beam, or by using different frequencies, among other techniques.

C. Security

Holography can also be used in security applications.Complex holograms are much more difficult to reproduce compared to static images. For this reason, holograms are often placed on valuable items to reduce the chances of forgery. Common security applications of holograph include labels on credit cards and images embedded in government currency. Important documents such as passports and identification cards also often use them to discourage illegal reproduction.

D. *Holographic Sensors*

A holographic sensor is a device that comprises a hologram embedded in a smart material that detects certain molecules or metabolites. This detection is usually a chemical interaction that is transduced as a change in one of the properties of the holographic reflection (as in the Bragg reflector), either refractive index or spacing between the holographic fringes. The specificity of the sensor can be controlled by adding molecules in the polymer film that selectively interacts with the molecules of interest.

D. *Hologram Making Recent News*

Recently thousands of people protested against a draconian law which endangered civil liberties in Spain. To challenge

the legislation passed, the activists called on people all over the world to volunteer to become a hologram in the protest. It has been world's first holographic protest.

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Conclusion

Holography has proved to be a true three-dimensional photographic technique, which means that it's aware of the depth of the space. Capability to record the phase information of the light is the main difference distinguishing it from traditional photography. The only way to store the phase of light is by utilizing the interference phenomenon. A coherent light source is essential to light interference, thus the breakthrough on laser technology lead to the rapid development of holography.

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In the end we saw the various applications of holography and saw that there is a great potential which lies in it. Especially in the field of data storage, when the current technology reaches its limit, the holographic method might be the next-generation solution. Further, the growing 3D entertainment demand is also an opportunity for holography.

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